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Proposal of a Model for Water Usage: Revenue Estimation in Brazil Hydrographic Basin

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Abstract. In order to improve the quality of aquatic ecosystems, a water collection instrument was established in the National Water Resources Policy (PNRH), with the purpose of collecting and allocating resources to the management of water systems, as well as stimulating the conscious and efficient use of water, with the direct finality of reducing the rates of waste and pollution of water sources. This instrument guided the definition of the objective from the present research, which is to estimate the collection of the Pianco-Piranhas-Açu Basin, located between the State of Paraiba and Rio Grande do Norte, to be calculated with a mathematical model of collection by the multiple water uses that consider volumes consumed, captured and for the discharge of effluents. To do so, it was analysed the main collection models adopted in Brazil to finally define the best algorithmic basis. Analysing the results, it was observed that the planned resources still do not provide a sustainable application of the real situation of the analysed basin, requiring further research to better understand the peculiarities of the region, given that the estimated collection is insufficient to provide the necessary infrastructure for Pianco-Piranhas-Açu (Brazil) river's basin management system. Therefore, this situation serves to alert public water management bodies about the modelling to be used and the urgency of implementing the charging instrument, given that it could improve the quality of the hydrographic basin studied.

Keywords. Water systems; Management; Collection; Water users.

1. Introduction

Even though it may seem banal to talk about water, because we are so used to its presence that we only realize its importance when we need it, water is the constituent element of organisms and the structuring element of the most diverse ecosystems. We constantly carry out a series of activities almost without thinking that would not be possible if there were no water.

The central discussion about hydric resources brings a concern that is becoming apparent as the population increases and, along with it, the use of water - a finite resource. What can be noticed is that these multiple uses made by all sectors of society, such as industry, agriculture, supply, among others, are being made in an uncontrolled way. Besides the irrational use of water, there is still the problem of pollution, because surface waters are characterized as the most vulnerable to pollution and scarcity due to the easy accessibility for the disposal of industrial and domestic effluents, which makes water resources scarce not only in quantity, but also in quality. According to the United Nations Organization (UNO), it is estimated that by 2050 more than 2 billion people will be without water available for their most basic needs (ANA, 2005).

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In order to preserve this natural asset, some existing instruments are being put into practice. The application of these economic instruments in water management aims to encourage rational consumption. In the quest to assign an economic value to water, Federal Law n° 9.433 (Brazil, 1997) introduced charging for the use of water, in the Hydrographic Basins (BCH) in Brazil, which, due to the growing hydric deterioration and scarcity of water that causes the economic valuation of hydric resources, adopts water resources as a limited natural resource endowed with economic value.

Charging for the use of water began in waters owned by the Union, through the deliberation of the Hydrographic Basin Committees. In Brazil, charging can only be implemented if approved by the Hydrographic Basin Committee (CBH) and by the National Council of Hydric Resources (CNRH) and/or by the State Council of Hydric Resources (CERH). The implementation of the charge will result from a "pact" signed between the public authorities (federal, state and municipal), the user sectors and civil organizations, with technical support from the ANA (National Water Agency). The mechanisms and values can be proposed by the CBH, but must be approved by the respective Water Resources Council - National or State - and the uses of capture, consumption, effluent discharge and basin transposition will be charged (ANA, 2009).

Marques and Comune (1996, p.23) explain that the problems of degradation and/or exhaustion occur when the costs resulting from the use of these resources are not considered: "Decisions taken only based on private costs, assuming zero cost for the environmental resource, cause the demand for the zero cost factor to be above the level of economic efficiency, and may lead that resource to complete exhaustion or total degradation.

As cited in the Resource Plan of the Pianco-Piranhas-Açu River Watershed (2016), the Northeast region of the country is characterized in terms of water resources by presenting a negative meeting of factors that challenge management: high water demand (mainly for human supply and irrigation) and high pollution load of domestic sewage associated with low water availability, characteristic of the semi-arid climate, in which many rivers are intermittent.

Based on this context, the main objective of this research is to estimate the collection of the Piancó-Piranhas-Açu basin using a mathematical model of collection that meets the peculiarities of the region studied and to analyse the financial feasibility of whether it is sufficient to finance the necessary infrastructure.

2. Materials and Methods

2.1 Study area

The Pianco-Piranhas-Açu River Hydrographic Basin (Fig. 1) is totally inserted in the semi-arid climate of the Northeast of Brazil, with a total drainage area of 43,681.50 Km^2, of which 26,183.00 Km^2, corresponding to 60% of the area in the State of Paraiba, and 17,498.50 Km^2, corresponding to 40% of the area in the State of Rio Grande do Norte. It covers 147 municipalities, 45 of them in the State of Rio Grande do Norte and 102 in the State of Paraiba, and has a total population of 1,363,802 inhabitants, 914,343 inhabitants (67%) in the State of Paraiba and 449,459 inhabitants (33%) in the State of Rio Grande do Norte.

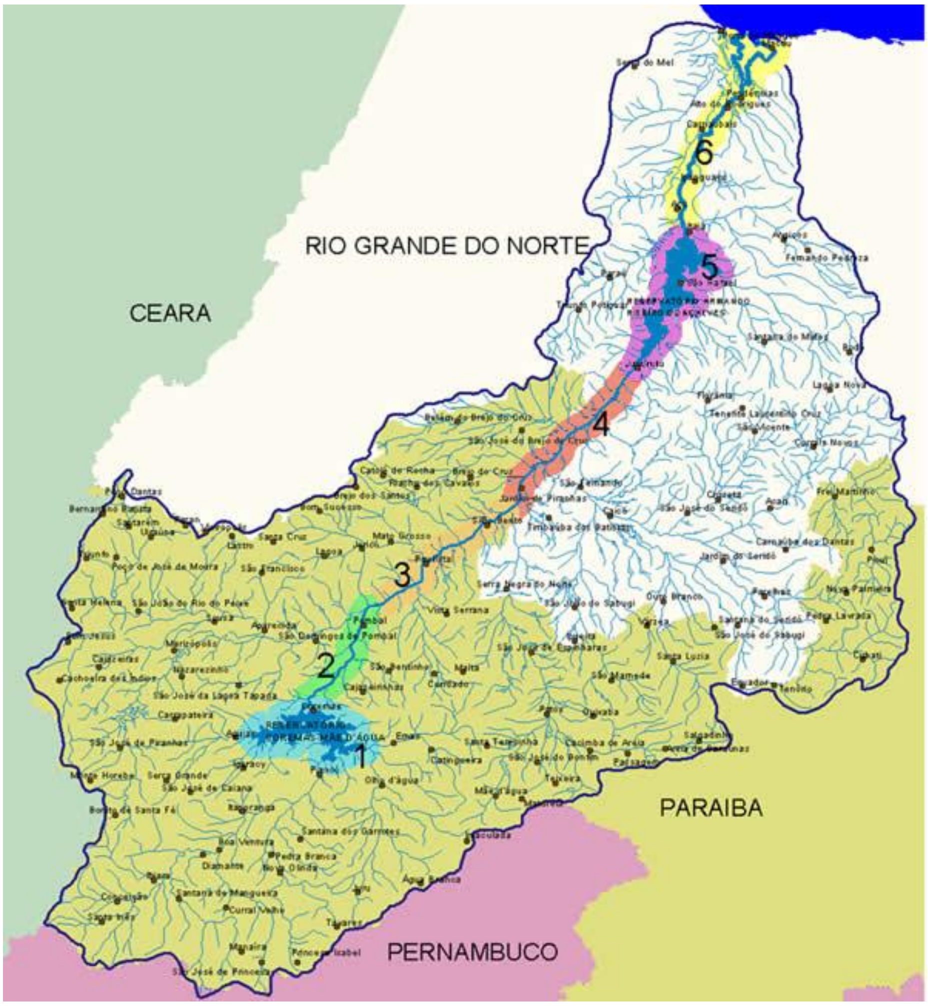

Figure 1. Location of the hydrographic basin of the Pianco-Piranhas-Açu Rivers.
Source: (AESA, 2018)

2.2 Collected Data and Collection Model Used

The main data were taken from the Pianco-Piranhas-Açu Water Resources Plan, which matches water availability, in qualitative and quantitative terms, with water demands, shows the current situation of the hydrographic basin, specifying possible uses in the basin, establishing from the water balance to concrete actions for the development of its resources, This is the most effective mechanism of dialogue with the territorial environmental management, because the assignment of classes conditions the type of activity that will be implemented. Also verified are the types of users, the granting instruments, and the quantities that a given authorized user can use, with use being conditioned to compliance with the terms of the grant. The user that has been granted a concession is charged for the use of water resources, whose values are defined by the committee, to be collected by ANA - National Water Agency and used to pay for the recovery actions of the hydrographic basin foreseen in the plan.

The revenue was estimated taking into consideration the components: a) abstraction of raw water; b) water consumption of each sector; and, c) quality of the effluents discharged. In estimating the potential collection of the charge for the use of water in the basin of the Pianco-Piranhas-Açu rivers we used as a reference the mechanisms and amounts charged for the use of water resources in the Hydrographic Basin of the São Francisco River, a model approved by the National Council of Hydric Resources (CNRH) and executed by the National Water Agency

(ANA), which is closer to the peculiarities of the region studied. Thus the amount to be paid by each user by the following Eq. 1:

$$Value_{full}=\left(Value_{Cap}+Value_{Con}+Value_{Lan}+Value_{Tran}+Value_{Ru}+Value_{E}\right)*K_{m} \quad (1)$$

where: $Valor_{full}$ - annual water payment referring to all uses; $Valor_{Cap}$ - annual payment referring to the abstraction of raw water made by the uses; $Valor_{Con}$ - annual payment referring to the users' consumption of raw water; $Valor_{Lan}$ - annual payment referring to the discharge of organic matter load; $Valor_{Tran}$ - annual payment referring to the transposition of the São Francisco River; $Valor_{Ru}$ - annual payment referring to the uptake and consumption in the rural sector; $Valor_{E}$ - annual payment referring to the production of electric power in small plants; and K_m - Referring to the effective return of the collected resources, it will be considered equal to 1 and when there is no return to the basin it will be equal to zero.

To calculate the value of the raw water withdrawal component, Eq. 2 is more appropriate:

$$Value_{Cap}=Q_{Cap}*PUP_{Cap}*(K_{Cap\ Class}*K_{t}) \quad (2)$$

where: $Valor_{Cap}$ - annual payment for water abstraction; Q_{Cap} - annual volume of water abstracted (m^3/year), according to the allocation data; PUP_{Cap} - unitary public price for surface abstraction (R$/$m^3$); $K_{Cap\ Class}$ - coefficient that takes into account the framing class of the water body; K_t - coefficient that takes into account good practices for water use and conservation.

The values defined for the coefficient $K_{Cap\ Class}$ are shown in the following:

Board 1. Amounts applied in the São Francisco River Basin

	Class	Value
$K_{Cap\ Class}$	1	1.1
	2	1.0
	3	0.9
	4	0.8

Source: ANA (2010).

The value of the water consumption component for each sector is calculated by Eq. 3 below:

$$Value_{Con}=(Q_{Cap}-Q_{Lan})*PUP_{Con}*K_{Con} \quad (3)$$

where: $Valor_{Con}$ - annual payment for water consumption; (Q_{Cap} - annual volume of water captured, according to grant values; Q_{Lan} - annual volume of water released, according to grant values; PUP_{Con} - Public Unit Price for water consumption R$/$m^3$; - coefficient that takes into account the specific objectives to be achieved by charging for water consumption, it is recommended to be equal to K_t, according to CBHSF deliberations.

The value of the quality component that deals with effluent discharge can be calculated by Eq. 4 below:

$$Value_{BOD}=(C_{BOD} * Q_{Lan})*PUP_{Lan}*K_{Lan} \quad (4)$$

where: $Valor_{BOD}$ - annual charge value for the release of organic load (R$/year); C_{BOD} - annual average concentration referring to the Biochemical Oxygen Demand of 5 days and 20 days (BOD5,20) of the effluent released; Q_{Lan} - annual volume of water released; PUP_{Lan} - public unit price for dilution of organic load (R$/kg); K_{Lan} - coefficient that takes into account the specific objectives to be achieved by charging for the release of organic load, which will be equal to 1 (one) until further deliberation by the CBHSF.

Technical Note nº.06 of the National Water Agency (2010), mentions the issue of pollution, which requires a certain amount of water to dilute its pollutant load released into the water body (CO_{BOD}) and is calculated by multiplying the average annual concentration relating to BOD5,20 of the effluent released by the annual volume of water released (Q_{Lan}) as follows:

$$CO_{BOD}=C_{BOD}\times Qlan \quad (5)$$

Thus, the Basic Unit Prices (PUB) in effect in 2010 and taken into consideration by the São Francisco River Basin Committee were established at the following values presented in Board 2:

Board 2. Public unit price according to water uses.

Public Unit Price	PUP	Value (R$/m³)
Raw water intake	PUPCap	0.01
Raw water consumption	PUPCons	0.02
Launch of organic load – $BOD_{5,20}$	PUBLan	0.10

Source: ANA (2010).

I remind you that these public unit prices for each scenario and year analyzed were corrected by the average inflation for the analyzed period from 2017 to 2032 and were collected from IBGE.

Regarding the demand projections, the Piancó-Piranhas-Açu Water Resources Plan was taken as a reference, referring to the analyzed basin, which shows the demands for human supply, livestock, industrial, irrigation and aquaculture (Board 3) for the years 2017, 2022 and 2032, years that in turn served as a basis for the billing projection, the target of this study.

Board 3. Demands of the analyzed watershed

	(m³/year)		
Demands	2017	2022	2032
Human Supply	100,536,768	99,369,936	104,699,520
Livestock	23,242,032	27,373,248	42,573,600
Industry	21,885,984	26,237,952	37,307,088
Irrigation	764,432,640	876,070,080	1,157,655,024
Aquaculture	314,792,352	322,644,816	339,043,536
Total	1,224,889,776	1,351,696,032	1,681,278,768

Source: PRH-PPA (2016).

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3. Results and Discussions

In order to obtain a better understanding of this estimated revenue, two scenarios were idealized and simulated considering the data presented and the components (uptake, consumption and discharge), and variation of the framing class according to CONAMA's Resolution 357/05.

3.1 Scenario I - Framework Class II

For Scenario I, Class II was used, thus, for the capture component, the value of "Q" _"Cap" refers to the annual volume of water captured (m³/year) and is associated with the allocation data and the type of user. Due to the lack of consistent data, current and future demands with losses in the water course of 35% of the estimated volume were considered as the capture flow. Regarding the 〖"PUP" 〗_"Cap" , we opted to use those measured by ANA, practiced in other interstate basins, with values from 2011, referring to the type of use, which in turn were updated taking into account the average inflation of 6% per year. The coefficient "K" _"Cap Class" that takes into account the class of classification of the water body, in this case Class II was considered.

For the analysis of the Effluent Release Component, the collection will be estimated based on the Biochemical Oxygen Demand (BOD5, 20) and is associated with the amount of organic matter contained in the effluent. An average of 350 mg/l, adopted by the Basic Sanitation Company of the State of São Paulo (SABESP), was considered. For irrigation, an average concentration of 50 mg/l was adopted.

The consumption component, in this scenario, refers to the annual payment for water consumption, that is, the measured value. We considered 70% of the volume of current and future demands, for urban and rural supply and industry, and 80% of this volume for other uses. The PUP's were updated considering the system's losses and the average inflation for the year. The constant "K" _"Con" is associated with the guarantee of service, and this coefficient considers the scarcity of water, which is characteristic of the region and is established by priority by type of use.

It is important to add in this scenario, that charging for effluent discharge is seen as the way to oblige the polluter to replace the expenses with effluent treatment, and that even paying for effluent discharge, it is still obliged to meet the discharge standards established by the environmental agency during licensing (ANA, 2014). The estimated values are described in Table 1 below:

Table 1. Revenue Estimation for Scenario I.

Year	Withdrawal (Capture+Consumption)	Launch
2017	R$ 7,159,329.32	R$ 1,015,487,555,28
2022	R$ 10,270,358.68	R$ 6,315,626,097.45
2032	R$ 16,487,718.01	R$ 2,188,596,887.69

3.2 Scenario II - Framework Class III

For Scenario II, Class III was used as the base, in the Capture Component, for this scenario the amount captured Q_{Cap} and PUP_{Cap} remained the same as Scenario I, what changed was the framework that is now Class III. For the Consumption Component, the Q_{Con} and PUP_{Con} values remain the same when compared to Scenario I, changing only the water guarantee values. For the Effluent Release Component, the same values as in Scenario I were considered. The estimated revenue can be seen below in Table 2:

Table 2. Revenue Estimation for Scenario II.

Year	Withdrawal (Capture+Consumption)	Launch
2017	R$ 7,069,397.57	R$ 1,117,036,310.81
2022	R$ 10,171,499.73	R$ 6,947,188,707.20
2032	R$ 16,400,823.45	R$ 2,407,456,576.45

Subsequently, to observe the return on investments, the investment plan was considered to determine the costs in the Pianco-Piranhas-Açu watershed, based on the information contained in the Action Plan contained in the Executive Summary of the Pianco-Piranhas-Açu Water Resources Plan (BRASIL, 2016).

The Action Plan is structured in 3 Components, which were grouped as follows: a) Component 1 - Water Resources Management: consisting of programs involving non-structural actions aimed at the management and sustainable use of water resources; b) Component 2 - Studies to Support the Management of Hydric Resources: made up of programs aimed at increasing knowledge about hydric resources to support management improvement; c) Component 3 - Studies and Projects for Structural Measures: made up of programs aimed at providing technical subsidies (studies and projects) for the structural actions necessary to improve the infrastructure of water supply and sanitation in urban and rural areas of the basin.

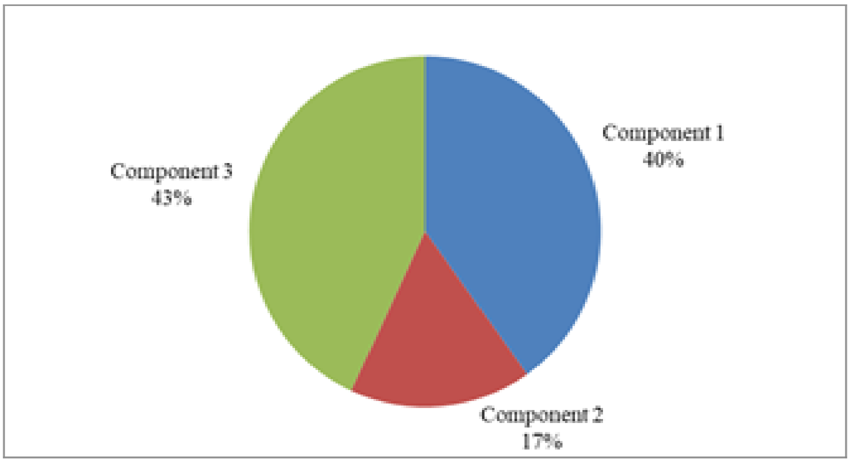

Figure 2 Distribution of financial resources foreseen in the water resources plan by component

Since the forecast for these investments is planned for a period of up to 20 years, as specified in the Action Plan for the studied watershed, and it is necessary to know how much of this total will be collected for each year (PMT), the estimated value can be determined through cash flow, amortized for the annual period with a minimum internal rate of return referring to the cost benefit analysis of 12% per year (i), allowing the calculation of the Present Value Factor (PVF) as presented in Eq. 6 below:

$$PVF(12\%.\ 20)=\frac{1-(1+0.12)^{-20}}{0.12} \quad (6)$$

Then the value of the annual installment can be calculated (PMT) by Eq. 7 below:

$$\text{PMT} = \frac{VP}{\text{PVF(i. n)}} \quad (7)$$

3.3 Estimation of the total revenue of the studied basin

3.3.1 Scenario I

For Scenario I, the large representativeness of the uses over the collected volume is due to the volume charged for the release of water volumes from the São Francisco River Basin, as well as the differentiated PUP's, considering the average inflation rate. Table 3 shows the total annual collection, should charging be implemented in the studied basin.

Table 3. Total Revenue in Scenario I

	(m³/year)		
Componet	2017	2022	2032
ValueCap	2,508,551.78	3,473,211.90	5,313,318.64
ValueCon	4,650,777.54	6,797,146.78	11,174,399.36
ValueLan	1,015,487.56	6,315,626.10	2,188,596.89
$Value_{Full}$	8,174,816.88	16,585,984.78	18,676,314.89
ValueCap	2,508,551.78	3,473,211.90	5,313,318.64

3.3.2 Scenario II

The Table 4 shows that Scenario II provided higher average annual revenue when compared to Scenario I. This was mainly due to the change in some parameters such as the water source class and guarantee levels. This was mainly due to the change in some parameters such as the class of the water source and the guarantee levels.

Table 3. Total Revenue in Scenario II

	(m³/year)		
Componet	2017	2022	2032
ValueCap	2,257,696.61	3,125,890.71	4,781,986.78
ValueCon	4,811,700.97	7,045,609.02	11,618,836.67
ValueLan	1,117,036.31	6,947,188.71	2,407,456.58
$Value_{Full}$	8,186,433.88	17,118,688.43	18,808,280.03
ValueCap	2,257,696.61	3,125,890.71	4,781,986.78

3.4 Financial feasibility analysis according to the master plan

After analysing the collection analysis in the different scenarios, it is possible to see that by 2032 this charging model should generate revenue to finance an infrastructure of R$ 127,398,740.00 for gross water withdrawal and R$ 82,943. 380.00 for effluent discharge as presented in the studies of the master plan of the studied hydrographic basin, also considering the capitalization period of 20 years and an internal rate of return of 12%, making use of the equation of calculation of the payments projects and using the French amortization system (Table Price) the following instalmentswere estimated annually to meet the value to be financed.

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3.5 Catchment and consumption

This can be illustrated by the following cash flow:

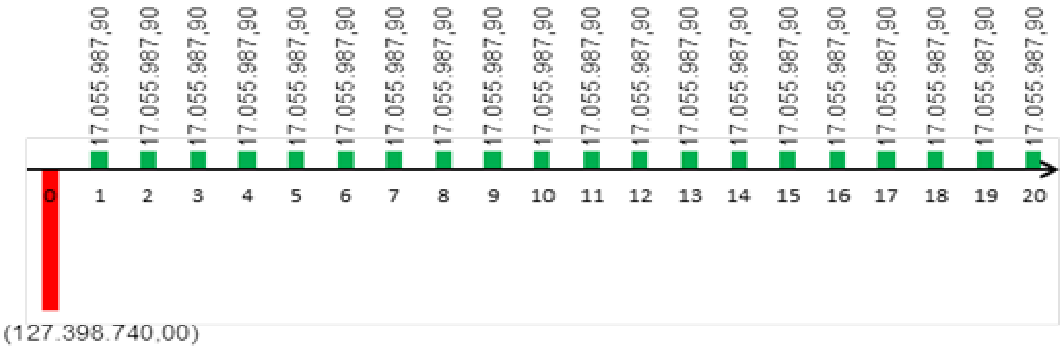

Figure 3. Cash flow projection for raw water withdrawal

3.6 Effluent Launching

This can be illustrated by the following cash flow:

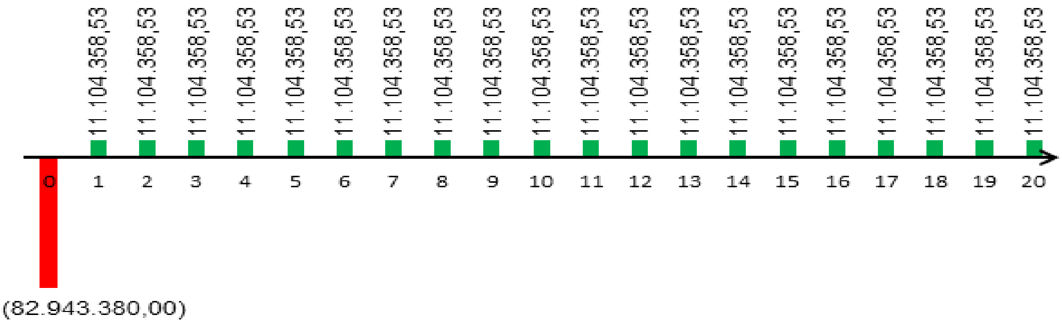

Figure 4. Cash flow projection for effluent discharge.

Based on the scenarios established, what can be observed is that the amounts collected for the removal of raw water and effluent discharge in the analysed watershed are below expectations when compared to the expected investments. In view of this, it is necessary to analysed other collection models already in practice in other basins, comparing them with other studies in the literature that use weighting variables that consider the particularities of the Pianco-Piranhas-Açu rivers. Thus the resources generated are not sufficient to supply the foreseen and planned costs of the management system of the hydrographic basin in question.

In view of the proposed scenarios it is understood that the amount raised for withdrawal was below what was expected for the year 2022 and also for 2032 when compared to the investments planned for the basin studied. In relation to the release, the amount collected was higher than the amount foreseen for application in the basin, overestimating the value. Therefore, as Assis and Vieira (2015) point out, it is necessary to analysed other collection models already in practice in other basins, comparing them with other studies in the literature that use weighting variables that consider the particularities of the Pianco-Piranhas-Açu River or even propose a collection model that projects a fair and sustainable collection. Thus the resources generated are not sufficient to supply the expenses of the management system of the hydrographic basin in question.

4. Conclusion

As exposed throughout this work, charging is a mechanism that has the purpose of collecting resources that will be reserved for investment in the watershed itself, as well as to stimulate the conscious and efficient use of water. It also has as a direct objective the reduction of waste and pollution rates of the water sources. With this, we would theoretically have an improvement in the quality of aquatic ecosystems. Thus, this work is based on a charging model that presented the amount of revenue from the multiple uses of water in the hydrographic basin of the Pianco-Piranhas-Açu river, alerting public bodies of water management to the urgency of implementing the charging instrument, bearing in mind that it could improve the quality of the basin under study.

To this end, despite having used the charging model applied in the basin of the São Francisco River adopted by the National Water Resources Council - CNRH, and the National Water Agency - ANA, the resources generated do not yet provide a practical application of the real situation of the basin analysed.

Therefore, it is concluded that further research in this area is necessary, considering that the annual collection represented is insufficient to provide support for the management system of the Pianco-Piranhas-Açu River basin. It is worth noting that future studies should propose collection models that consider the particularities of each region.

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